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(54) Abstract Title

**Forming a piezoelectric actuator of an inkjet printhead by coating an anti-oxidation film over exposed surfaces of an integral vibrator and chamber plate**

(57) Initially, a vibrating plate 20 is integrally formed with a chamber plate 10 which (optionally may be provided with an ink chamber 11) is loaded into a furnace 30 together with a metal powder 40 which has anti-oxidation properties (e.g. aluminium or chromium). The furnace is heated at a temperature of 600-1,500°C in a reducing atmosphere (e.g. hydrogen or argon) and/or a vacuum of $1.33 \times 10^{-6}$ - 6.6kPa. As the furnace is heated, the powder is melted such that it is coated over the exposed surfaces of the chamber plate and vibrating plate, to form an anti-oxidation metal film 80 over the exposed surfaces. The resulting structure is thermally treated in an oxidation atmosphere to oxidise the metal film to form an anti-oxidation film 50 over the exposed surfaces of the chamber plate and the vibrating plate. An oxide piezoelectric element 60 is laminated on the upper surface of the vibrating plate through a sintering process and an upper electrode 70 is then laminated over the oxide element to complete the actuator. Several other methods of forming the anti-oxidation film are disclosed. For example, the film may be deposited by a vacuum deposition process such as sputtering or evaporation (Figs.2,6). Alternatively, the chamber plate and vibrating plate are made of a material containing an anti-oxidation metal (Figs.3,7). Additionally, the ink chamber 11 may be formed following the heating and sintering steps using a patterning photoresist film mask (90,Fig.5) and etching process.

FIG.1

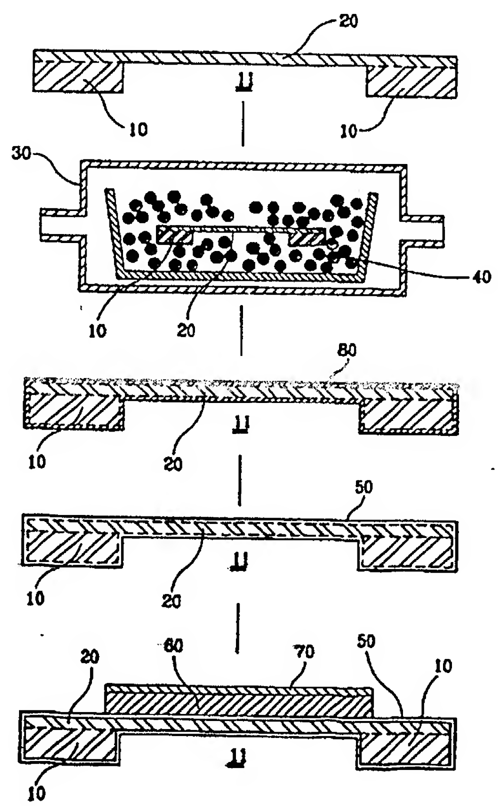


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FIG.1

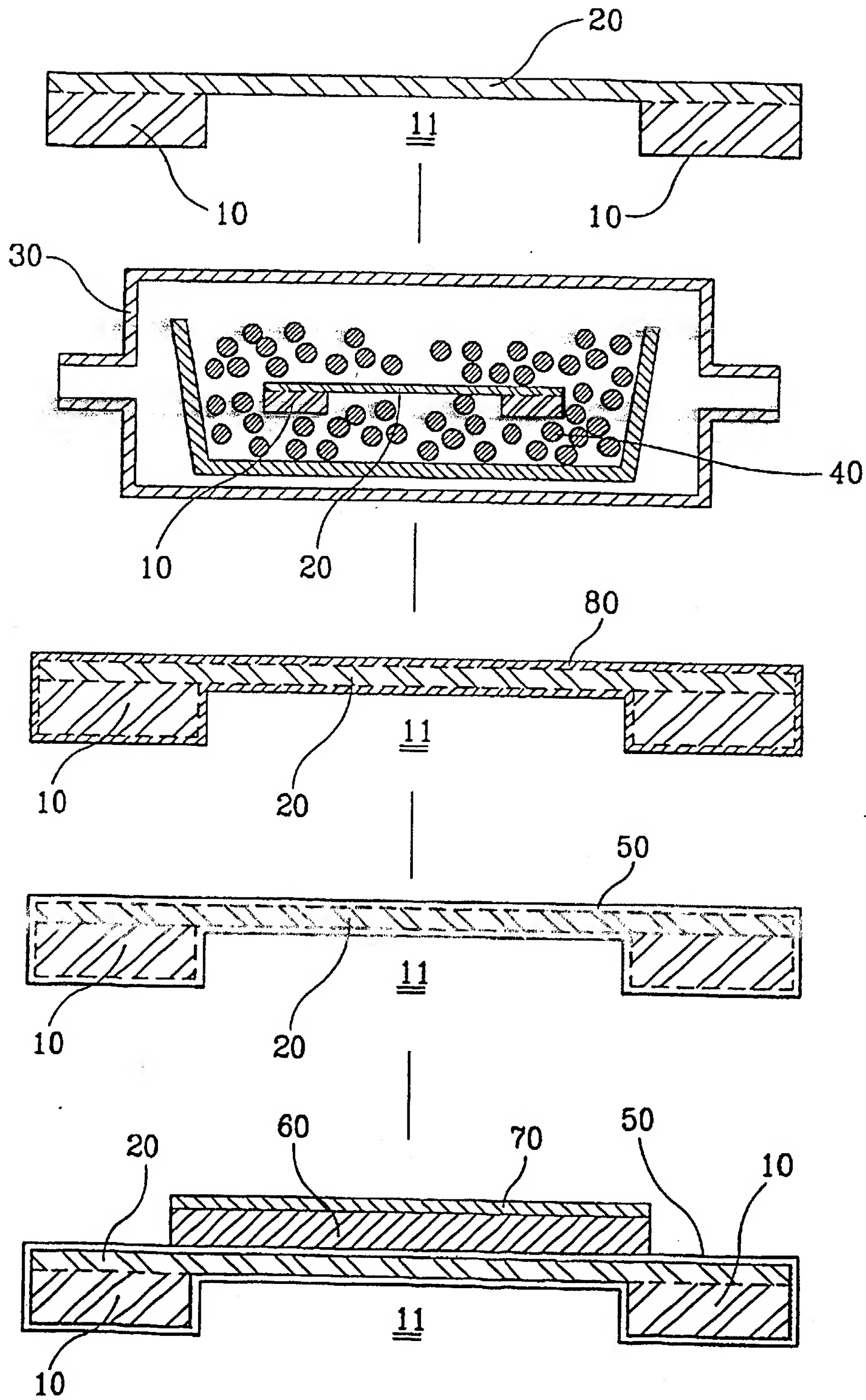

FIG.2

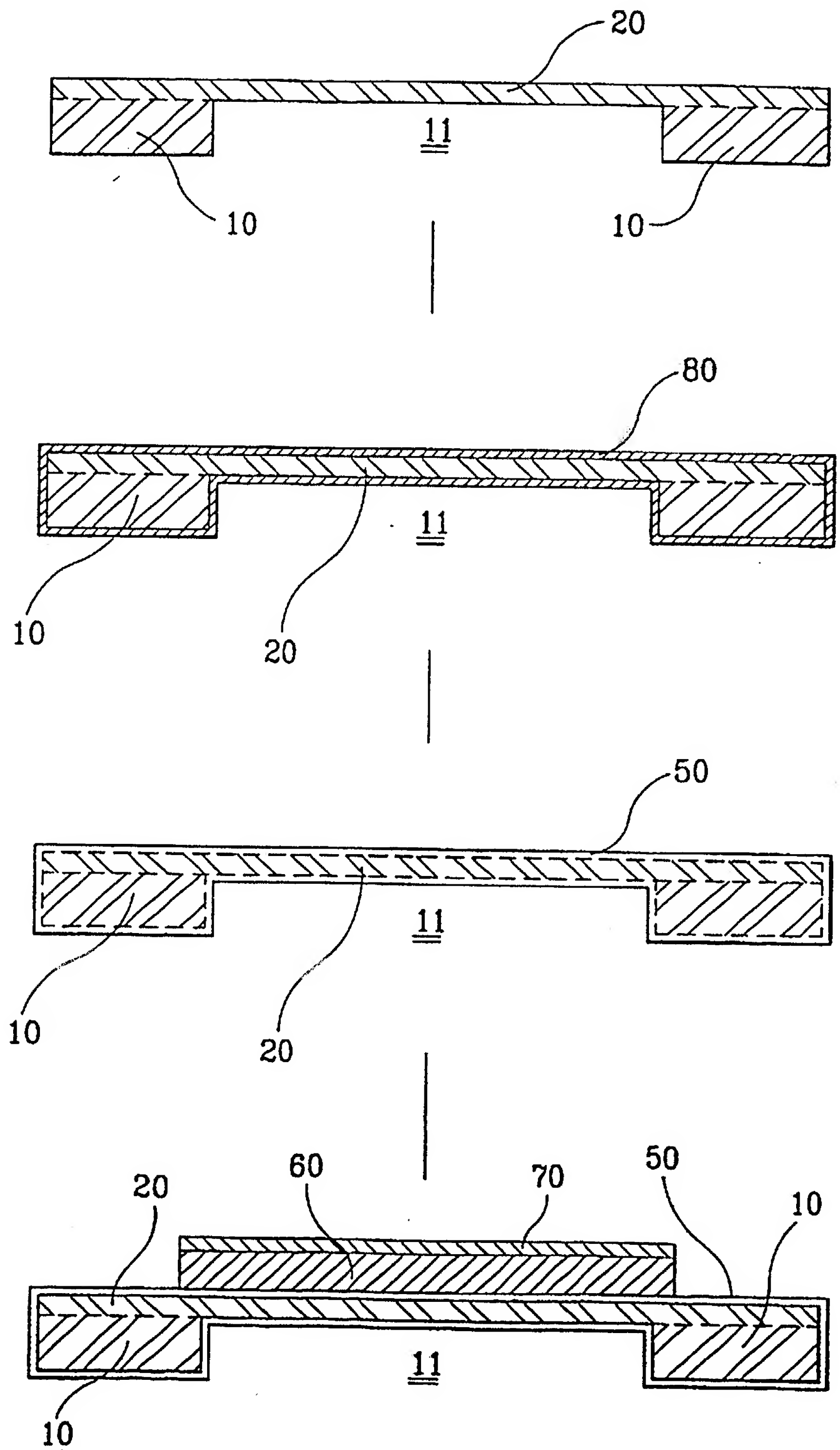

FIG.3

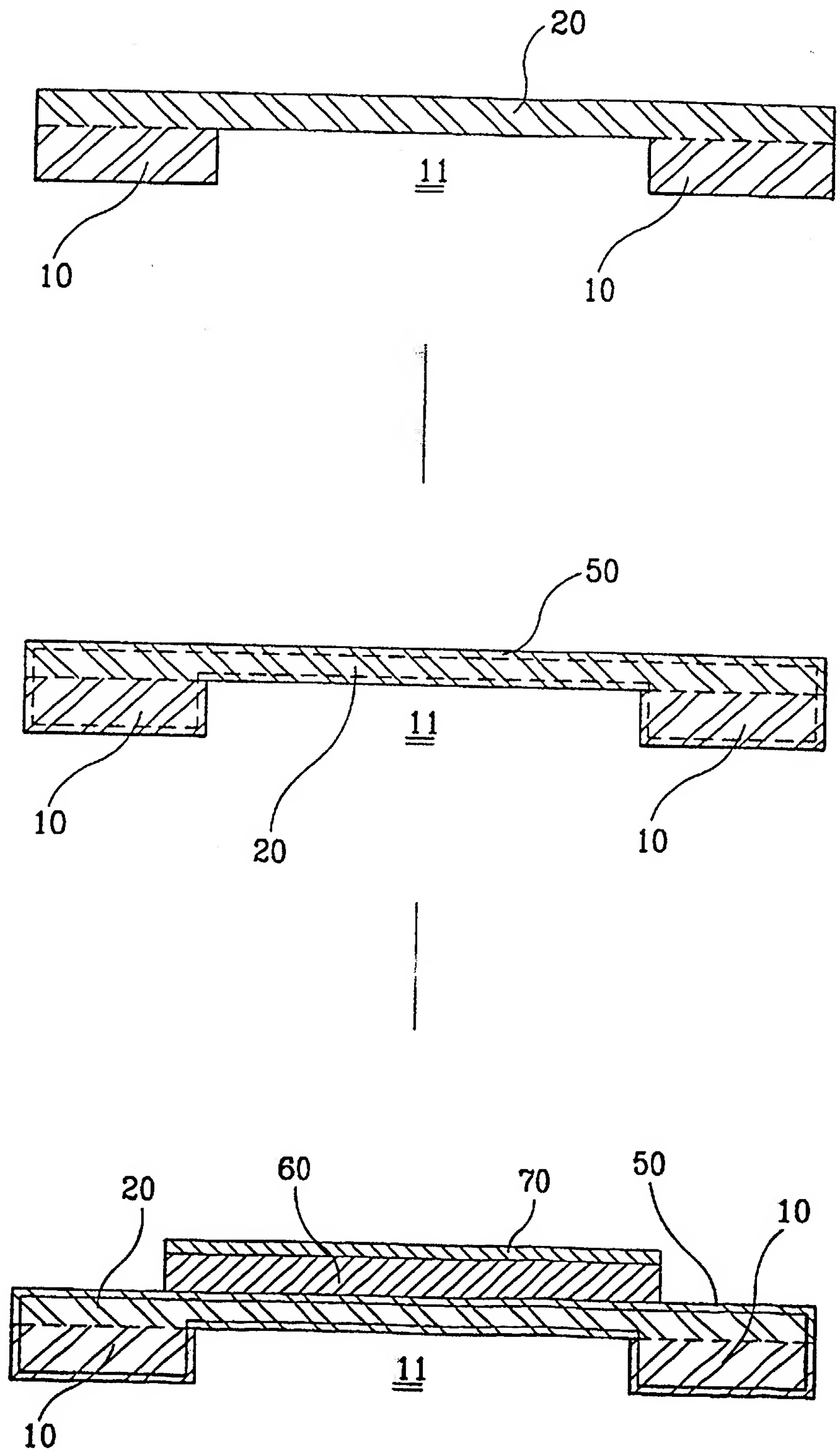

FIG.4

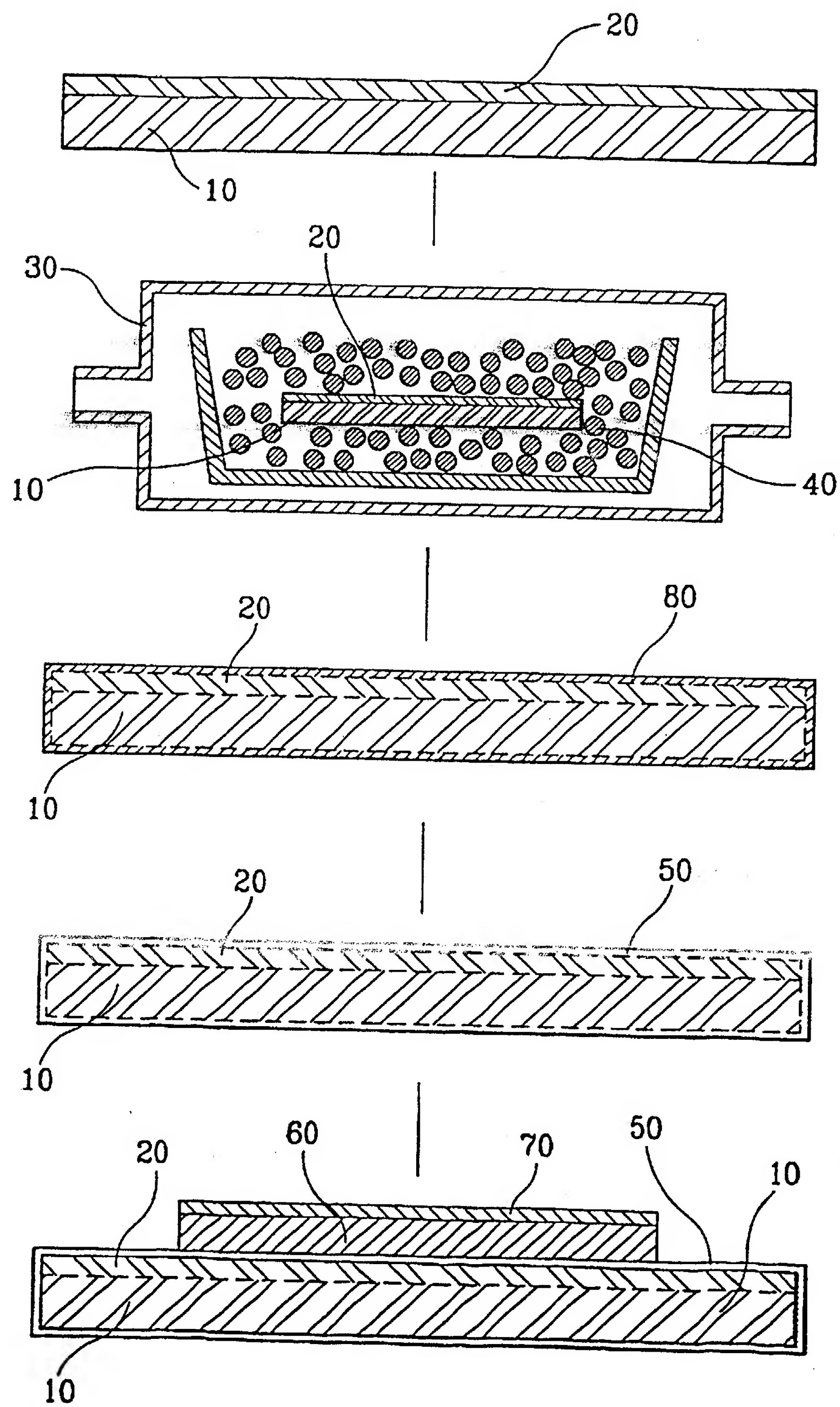

FIG.5

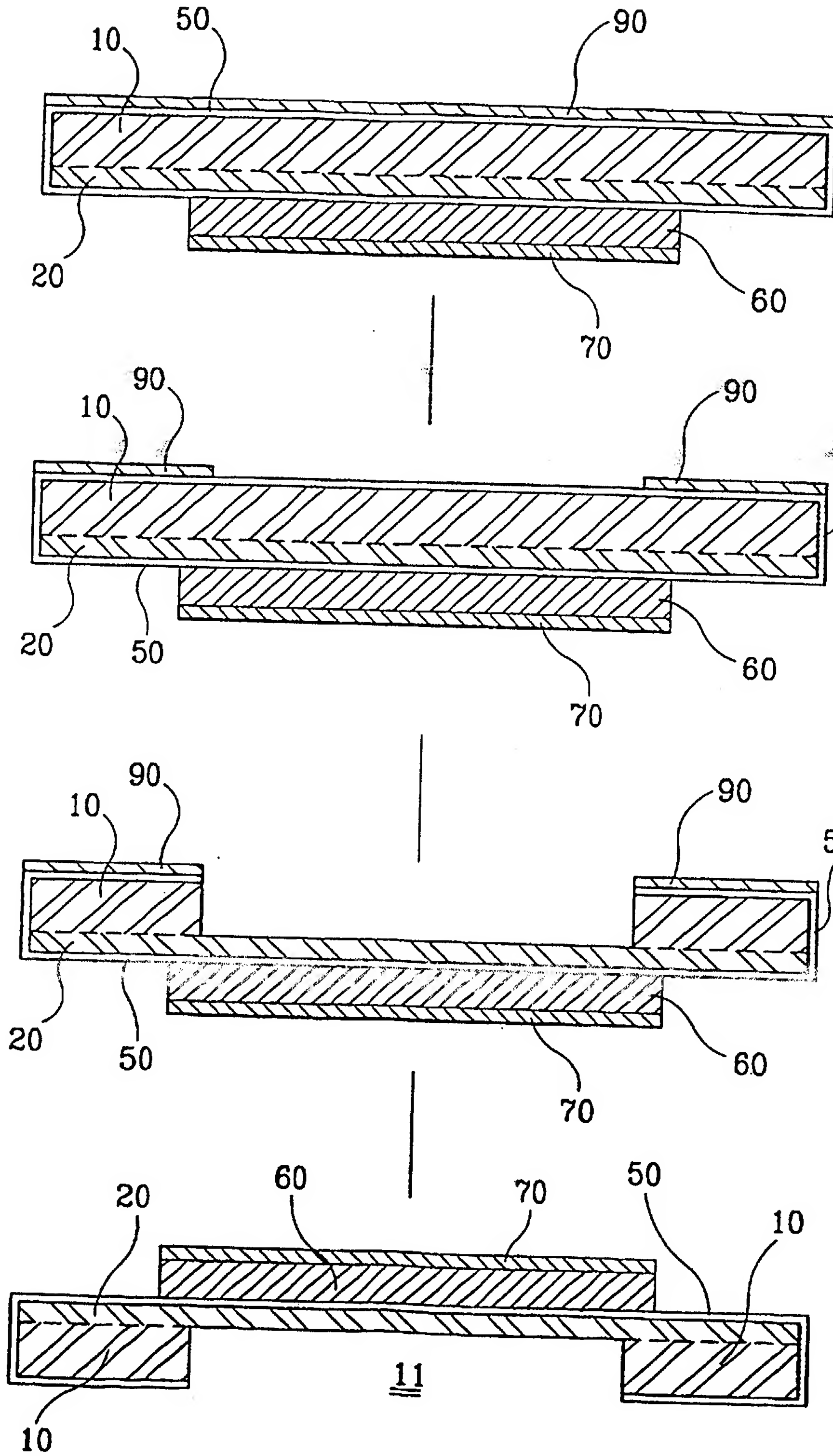
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FIG.6

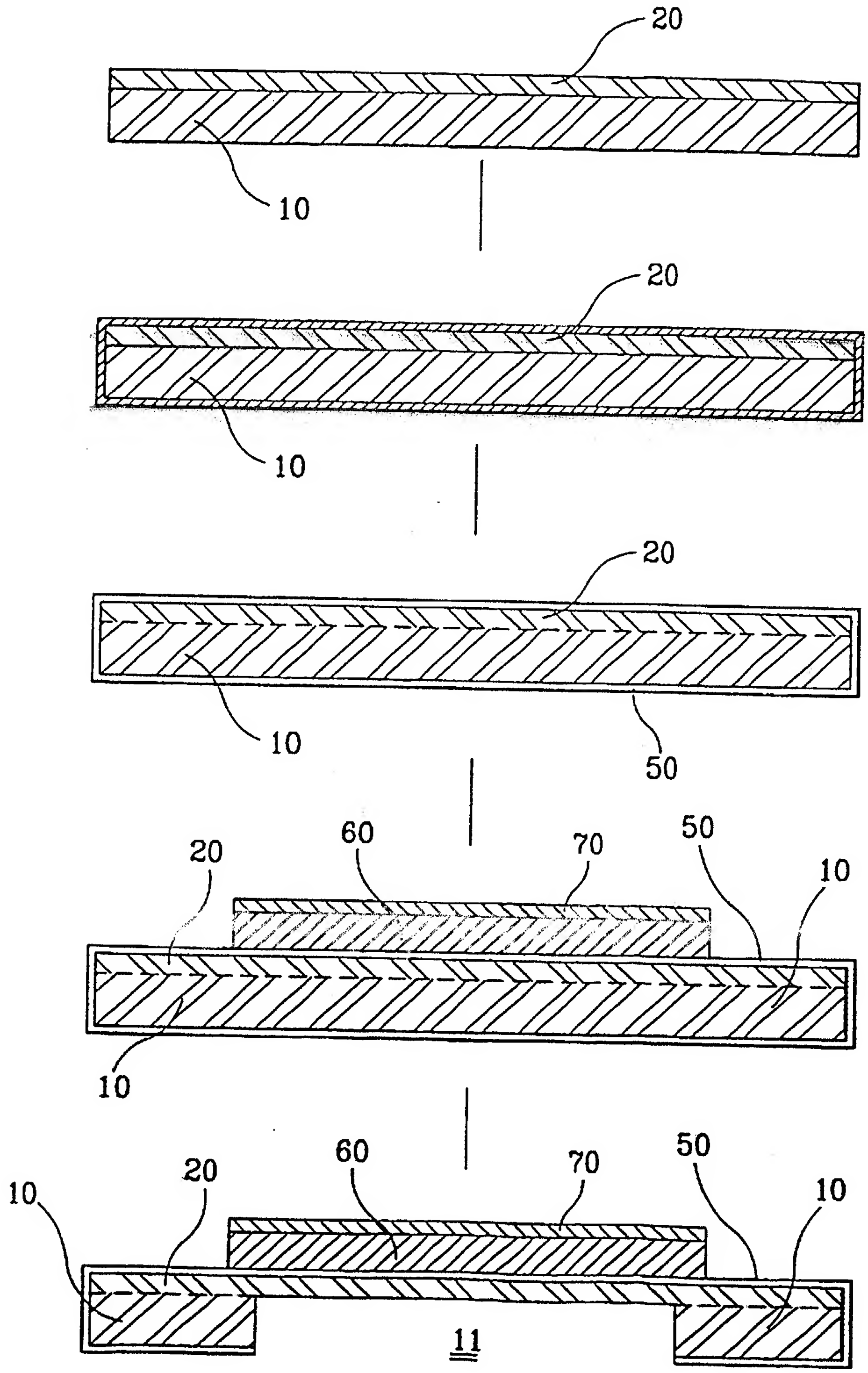


FIG.7

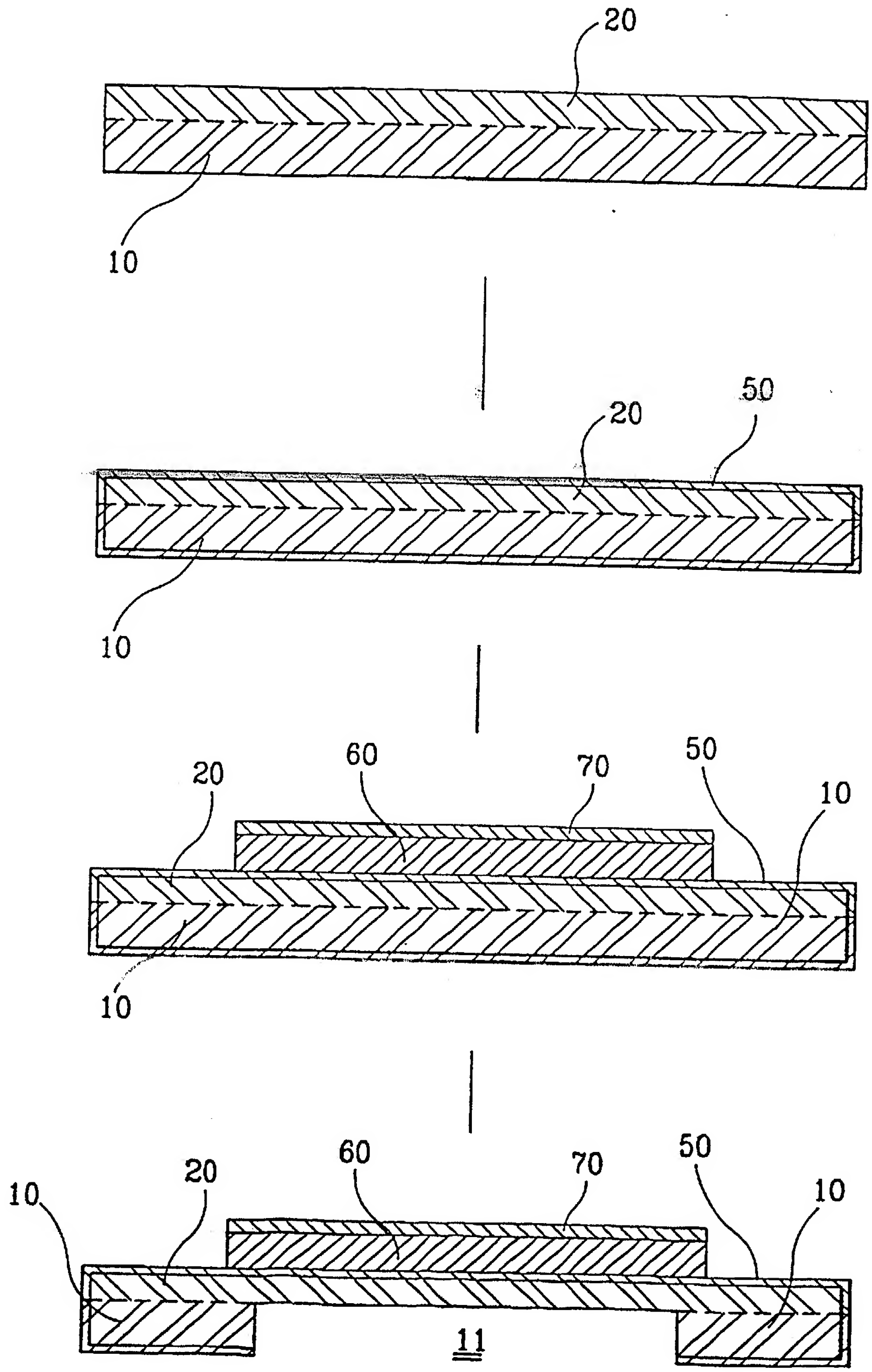
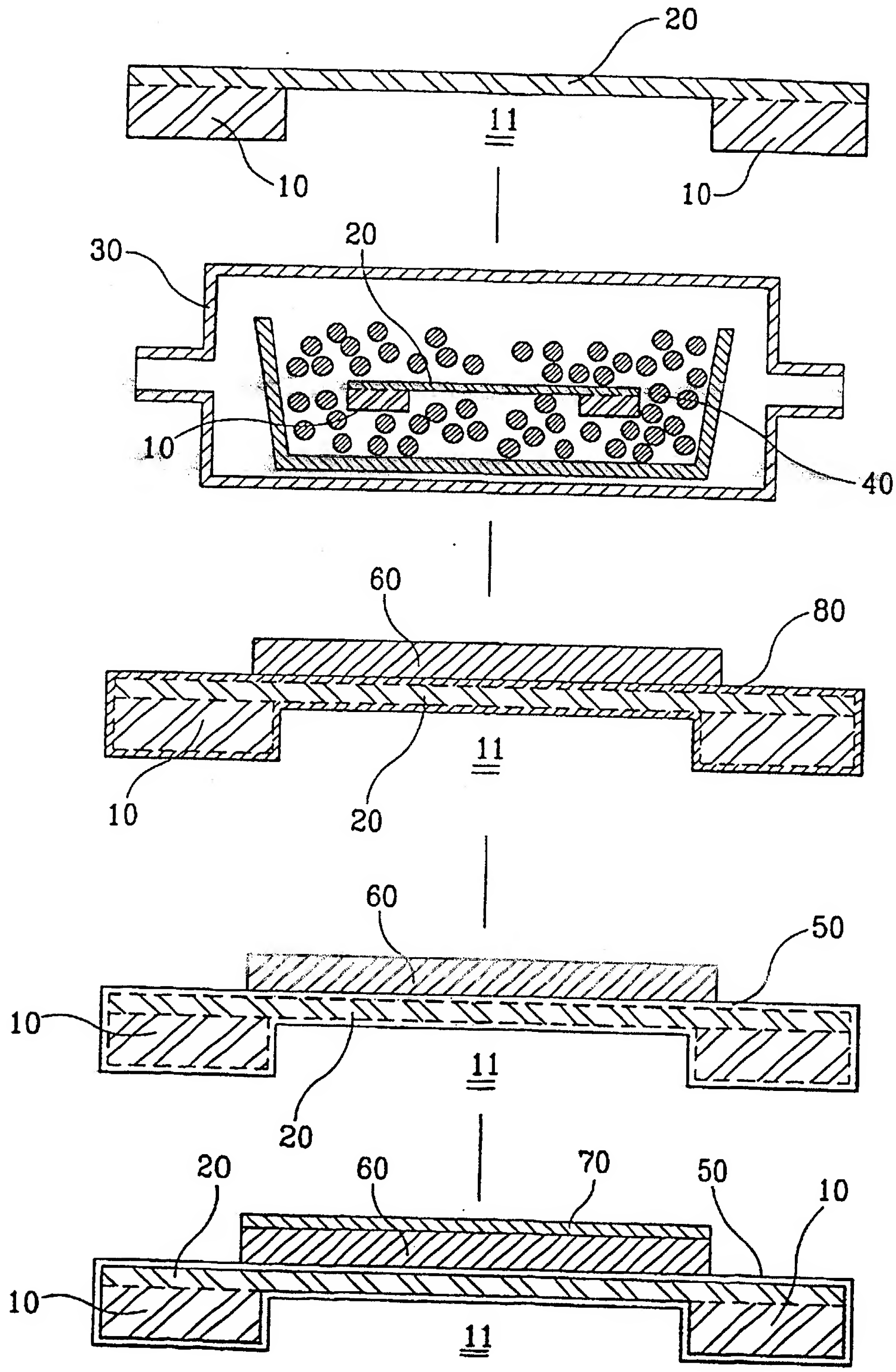


FIG.8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11

FIG.9

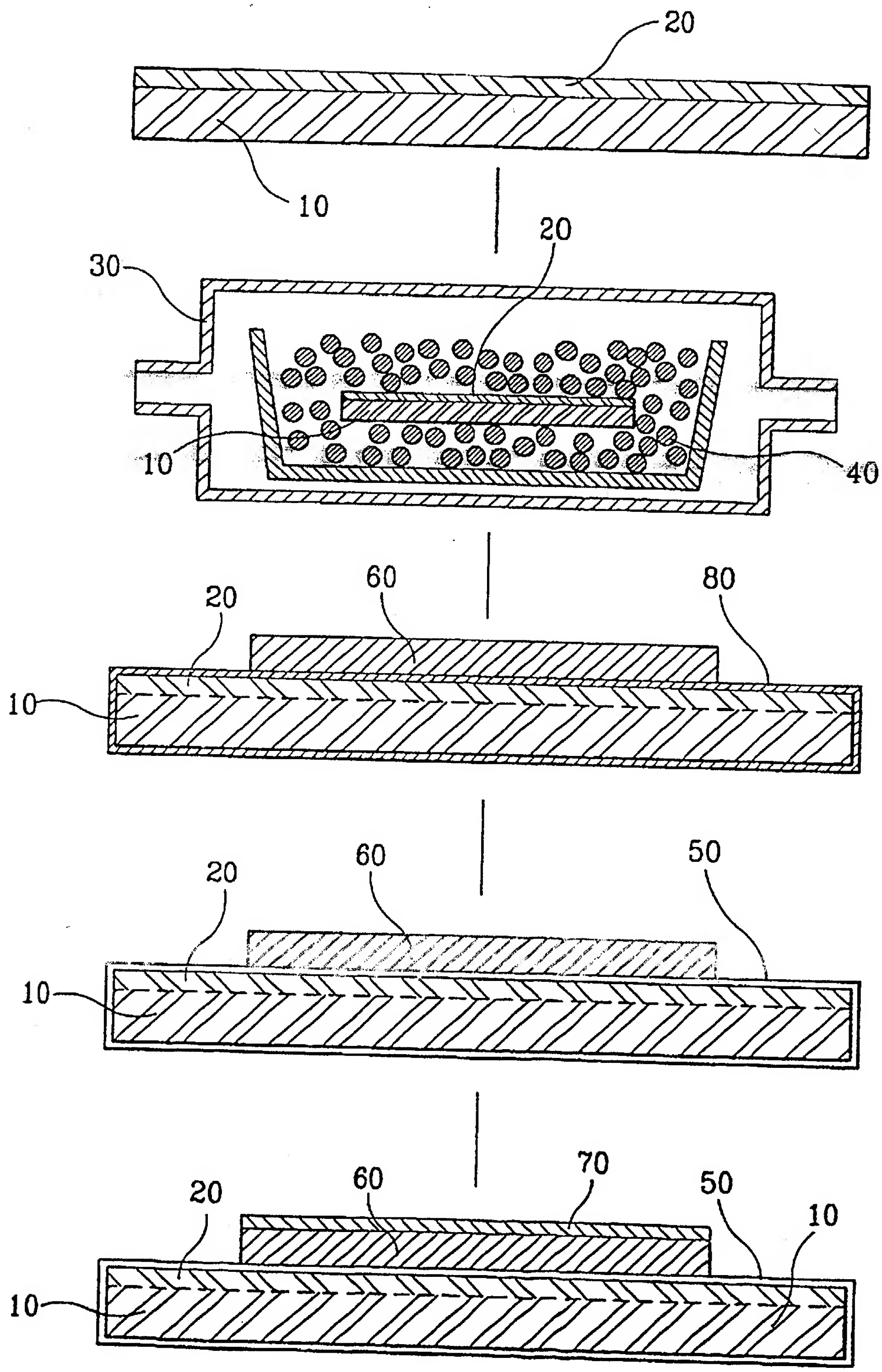


FIG.10A

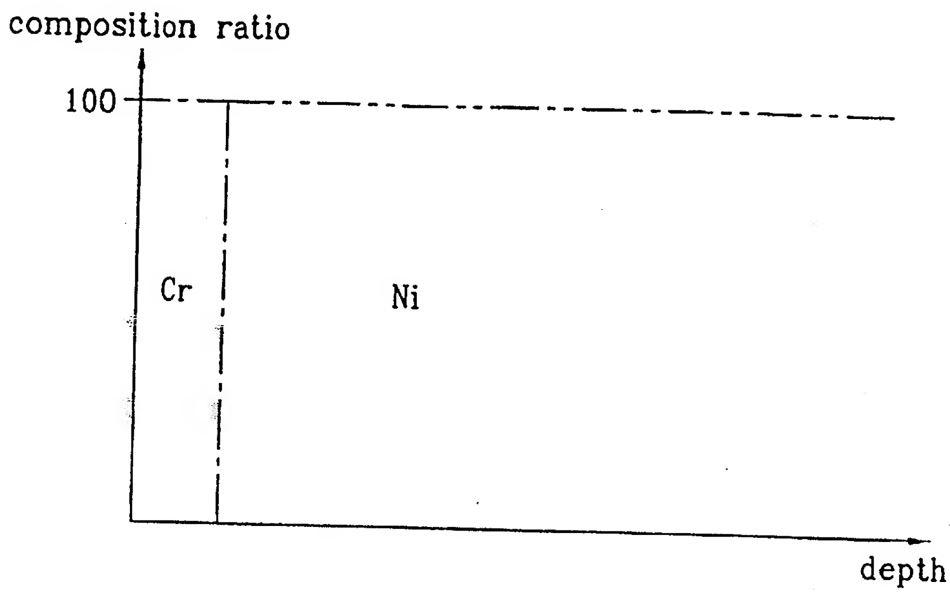



FIG.10B

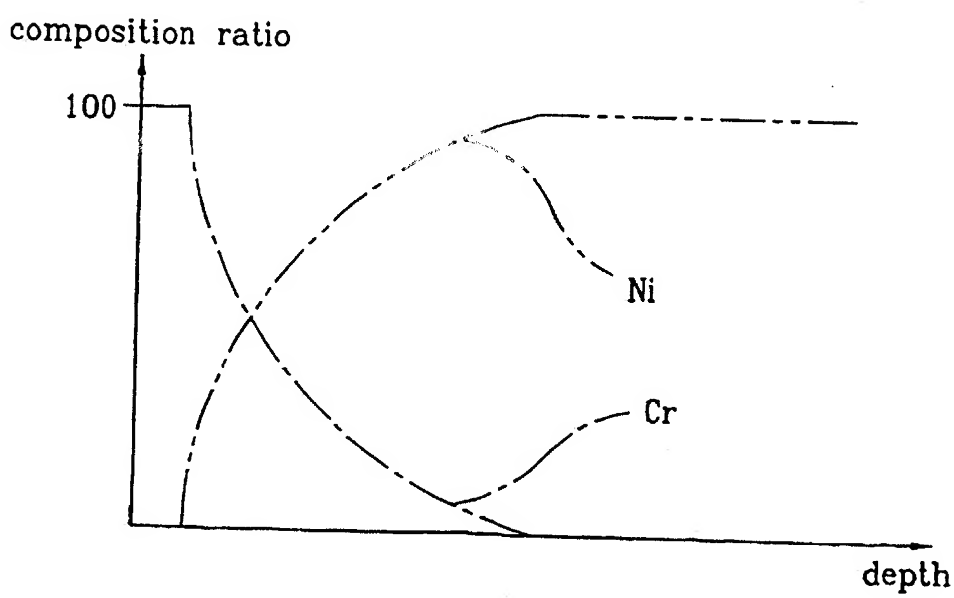


FIG.10C

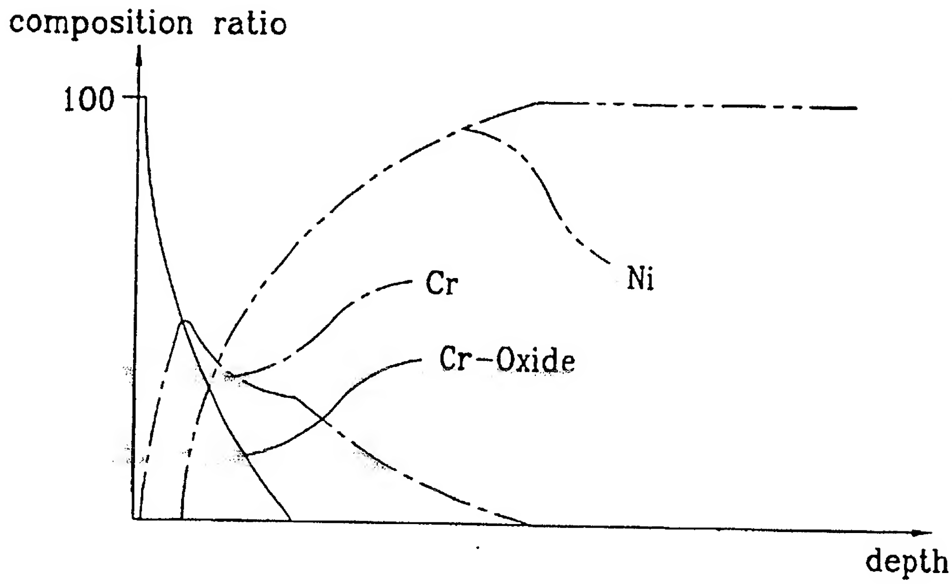
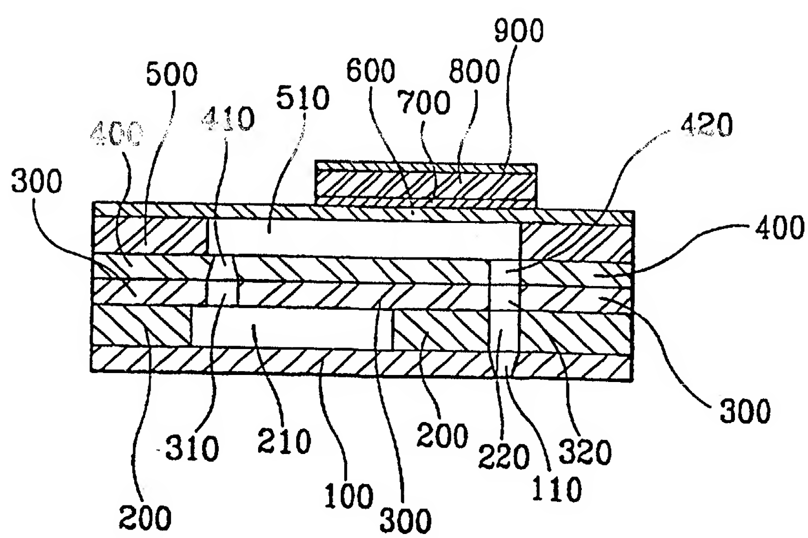



FIG.11
(CONVENTIONAL ART)



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# METHOD FOR FABRICATING ACTUATOR OF INKJET PRINTER HEAD

The present invention relates to a method for fabricating an actuator of an inkjet printer head, and more particularly to a method for fabricating an actuator of an inkjet printer head, in which an anti-oxidation film is formed over a vibrating plate integrally formed with a chamber plate, so as to prevent the vibrating plate from varying in physical properties and shape during a processing step for depositing oxide piezoelectric elements using a sintering process.

As well known, an inkjet printer head is a part of an inkjet printer for squirting or firing ink in the form of droplets using an actuator such as a piezoelectric element.

A vibrating plate is operatively connected to such an actuator comprised of a piezoelectric element in such a fashion that it is bent when the piezoelectric element is deformed due to an electrical force applied thereto, thereby outwardly discharging ink from a solution chamber.

Generally, oxide piezoelectric elements are mainly used as piezoelectric elements for printer head actuators.

In such printer head actuators, an oxide piezoelectric element used is configured to generate longitudinal expansion and contraction thereof as voltage is intermittently applied thereto, so that a vibrating plate attached to the lower surface of the oxide piezoelectric element is bent, thereby causing ink

contained in a chamber plate to be outwardly discharged. Thus, a printing is achieved.

Fig. 11 illustrates the structure of a general inkjet printer head which is commonly used.

Referring to Fig. 11, the inkjet printer head includes a nozzle plate 100, a reservoir 200, a channel plate 300, a restrictor plate 400, a chamber plate 500, and a vibrating plate 600. The nozzle plate 100, reservoir 200, channel plate 300, restrictor plate 400, and chamber plate 500 have a nozzle 110, a reservoir 210, a solution channel 310, a restrictor 410, and a solution chamber 510, which have different sizes and shapes, respectively. Solution passages 220, 320, and 420 having the same diameter are also formed through the reservoir 200, channel plate 300, and restrictor plate 400, respectively. Laminated on the vibrating plate 600 are a lower electrode 700, an oxide piezoelectric element 800, and an upper electrode 900.

The vibrating plate 600 is made of ceramic such as zirconia ($ZrO_2$). The vibrating plate 600 is formed by forming a green sheet using a ceramic material, and then sintering the green sheet at a high temperature, for example, about 1,500°C.

The lower electrode 700 and oxide piezoelectric element 800 are sequentially laminated on the vibrating plate 600. In particular, the lamination of the oxide piezoelectric element 800 is achieved using a well-known screen printing process. The laminated oxide piezoelectric element 800 is then sintered at a high temperature of about 1,100 °C.

Ceramic, which is used to form the vibrating plate 600,

exhibits a poor workability in a completely sintered state. For this reason, it is impossible to form a micro structure using such a ceramic material. Furthermore, a structure, which is made of such a ceramic material, may be deformed during a processing step for providing physical properties associated with ceramic to the structure using a high temperature sintering process.

As a result, it is difficult to fabricate a structure having micro dimensions using ceramic. Where the vibrating plate 600 is mainly made of such a ceramic material, it exhibits poor mechanical properties. In this case, a high brittle fracture property may be exhibited.

Although the sintering temperature of the piezoelectric element 800 laminated on the vibrating plate 600 is lower than that of the vibrating plate 600, it is very high, i.e., about 1,100°C. For this reason, there may be a serious problem in that the vibrating plate 600, which has already been sintered, may vary in physical properties during the processing step for sintering the piezoelectric element 800.

Therefore, an object of the invention is to provide a method for fabricating an actuator of an inkjet printer head, wherein a vibrating plate is comprised of a metal thin plate and laminated with an anti-oxidation layer, so that its physical properties and shape are still maintained in a thermal process conducted at a high temperature, thereby achieving an improvement in the reliability associated with the performance.

Another object of the invention is to provide a method for

fabricating an actuator of an inkjet printer head, which is capable of preventing the actuator from being eroded due to its contact with ink, thereby achieving an enhancement in durability.

In accordance with the present invention, these objects are accomplished by providing a method for fabricating an actuator of an inkjet printer head comprising the steps of forming a vibrating plate in such a fashion that it is integral with a chamber plate, forming an anti-oxidation film to a desired thickness over exposed surfaces of the chamber plate and vibrating plate, and sequentially laminating a piezoelectric element and an upper electrode on the vibrating plate formed with the anti-oxidation film. Where the chamber plate has no solution chamber, the formation of a solution chamber in the chamber plate is carried out using an etching process after the lamination of the upper electrode. Thus, a desired printer head is fabricated.

The formation of the anti-oxidation film may be carried out in different manners in accordance with the materials of the chamber plate and vibrating plate and the oxidation method used.

Where the anti-oxidation film is formed over the chamber plate and vibrating plate, it is possible to directly laminate the piezoelectric element, which requires a sintering process at a high temperature for its lamination, on the vibrating plate. During the sintering of the piezoelectric element, the vibrating plate still maintains its physical properties by virtue of the anti-oxidation film. Accordingly, it is possible to more improve the reliability of the head fabrication and the resulting products.

Other objects and aspects of the invention will become apparent from the following description of embodiments with reference to the accompanying drawings in which:

Fig. 1 illustrates a method for fabricating an actuator of an inkjet printer head in accordance with a first embodiment of the present invention;

Fig. 2 illustrates a method for fabricating an actuator of an inkjet printer head in accordance with a second embodiment of the present invention;

Fig. 3 illustrates a method for fabricating an actuator of an inkjet printer head in accordance with a third embodiment of the present invention;

Fig. 4 illustrates a method for fabricating an actuator of an inkjet printer head in accordance with a fourth embodiment of the present invention;

Fig. 5 illustrates sequential processing steps for forming a solution chamber in accordance with the fourth embodiment of the present invention;

Fig. 6 illustrates a method for fabricating an actuator of an inkjet printer head in accordance with a fifth embodiment of the present invention;

Fig. 7 illustrates a method for fabricating an actuator of an inkjet printer head in accordance with a sixth embodiment of the present invention;

Fig. 8 illustrates a method for fabricating an actuator of an inkjet printer head in accordance with a seventh embodiment of

the present invention;

Fig. 9 illustrates a method for fabricating an actuator of an inkjet printer head in accordance with an eighth embodiment of the present invention;

Figs. 10A to 10C are graphs respectively depicting a variation in composition ratio exhibited between a nickel substrate and a chromium layer formed on the nickel substrate before and after the formation of an anti-oxidation film in accordance with the present invention, depending on the depth of the nickel substrate; and

Fig. 11 is a cross-sectional view illustrating the structure of a general inkjet printer head.

Fig. 1 illustrates a method for fabricating an actuator of an inkjet printer head in accordance with a first embodiment of the present invention. Referring to the uppermost view of Fig. 1, a vibrating plate 20 is shown which is formed integrally with a chamber plate 10 provided with a solution chamber 11.

A single body may be prepared to form the chamber plate 10 and vibrating plate 20 integrally with each other. In this case, the solution chamber 11 is subsequently formed in the portion of the body corresponding to the chamber plate 10. Alternatively, the chamber plate 10 and vibrating plate 20 may be individually formed. After being formed with the solution chamber 11, the resultant chamber plate 10 is coupled with the vibrating plate 20 formed separably from the chamber plate 10.

The structure including the chamber plate 10 and vibrating

plate 20 integral with each other is then loaded in a container received in a heating furnace 30, together with metal powder 40 to be coated over the chamber plate 10 and vibrating plate 20.

For the metal powder 40, aluminum (Al) or chromium (Cr) may be mainly used which exhibit an anti-oxidation property. Nickel (Ni) or cobalt (Co) may be added to the aluminum or chromium.

An active agent adapted to provide an active coating of the metal powder 40 and an anti-sintering agent adapted to prevent the metal powder 40 from flowing and being sintered may be added in the furnace 30 in the form of powder in certain ratios with respect to the metal powder 40, respectively.

The active agent may include a halogen compound such as sodium chloride ($NaCl$) or nitrogen chloride ($NH_4Cl$). The anti-sintering agent may include alumina oxide ($Al_2O_3$) or zirconia ($ZrO_2$).

The furnace 30 is then heated at a high temperature in a desired atmosphere, for example, a reducing atmosphere containing reducing gas such as hydrogen ($H_2$) or an inert atmosphere containing inert gas such as argon (Ar), helium (He), or nitrogen ($N_2$), and/or in a vacuum condition of $10^{-5}$ to 50 Torr.

Preferably, the heating temperature of the furnace 30 is about 500°C or more.

As the furnace 30 is heated, the metal powder 40 is melted, so that it is coated over the exposed surfaces of the chamber plate 10 and vibrating plate 20 contained in the container, thereby forming an anti-oxidation metal film 80 over the exposed surfaces of the chamber plate 10 and vibrating plate 20.

The resulting structure coated with the anti-oxidation metal film 80 is thermally treated at a temperature of about 600 to 1,500°C in an oxidation atmosphere. By this thermal treatment, the metal film 80 coated over the exposed surfaces of the chamber plate 10 and vibrating plate 20 is oxidized, thereby forming an anti-oxidation film 50 over the exposed surfaces of those plates 10 and 20.

The anti-oxidation film 50 is very tight, namely, has a very high inter-grain density, so that it serves to prevent an intra-metal oxidation.

Preferably, the anti-oxidation film 50 has a thickness of about 0.03 to 5 μm. Where the anti-oxidation film 50 has a thickness exceeding the upper limit, the vibrating performance of the vibrating plate 20 is greatly degraded.

Thereafter, an oxide piezoelectric element 60 is deposited on a desired portion of the vibrating plate 20 formed with the anti-oxidation film 50 using a screen printing process, and then sintered at a high temperature of about 900 to 1,100°C. Finally, an upper electrode 70 is laminated over the oxide piezoelectric element 60. Thus, an inkjet printer head is produced.

Since the anti-oxidation film 50 is formed over the exposed surfaces of the chamber plate 10 and vibrating plate 20 in accordance with the above mentioned method, it is possible to protect the vibrating plate 20 during the processing step for sintering the oxide piezoelectric element 60 at a high temperature. Accordingly, it is possible to prevent the vibrating plate 20 from varying in physical properties or being

deformed.

Fig. 2 illustrates a method for fabricating an actuator of an inkjet printer head in accordance with a second embodiment of the present invention. In Fig. 2, elements respectively corresponding to those of Fig. 1 are denoted by the same reference numerals. Referring to the uppermost view of Fig. 2, a vibrating plate 20 is shown which is formed integrally with a chamber plate 10 provided with a solution chamber 11.

This embodiment is characterized in that an anti-oxidation metal film 80 is deposited over the exposed surfaces of the chamber plate 10 and vibrating plate 20 integral with each other by use of a vacuum deposition process such as a sputtering or evaporation process.

The deposition of the anti-oxidation metal film 80 may be achieved by depositing an oxidized metallic material over the exposed surfaces of the chamber plate 10 and vibrating plate 20. Alternatively, the deposition of the anti-oxidation metal film 80 may be achieved by depositing a metallic material containing an anti-oxidation metal.

Although the anti-oxidation metal film 80 is already in an oxidized state, its oxidation is further carried out when the chamber plate 10 and vibrating plate 20 deposited with the anti-oxidation metal film 80 are subjected to a thermal treatment at a temperature of about 600 to 1,500°C. As a result, a tight anti-oxidation film 50 with a very high density is formed over the exposed surfaces of the chamber plate 10 and vibrating plate 20.

Preferably, the anti-oxidation film 50 has a thickness of about 0.03 to 5 μm, as in the first embodiment of the present invention.

Thereafter, an oxide piezoelectric element 60 is deposited on a desired portion of the vibrating plate 20 formed with the anti-oxidation film 50, and then sintered at a high temperature of about 900 to 1,100°C. Finally, an upper electrode 70 is laminated over the oxide piezoelectric element 60. Thus, an inkjet printer head is produced.

In accordance with the second embodiment of the present invention, there is an advantage in that it is unnecessary to use the furnace 30 as required in the first embodiment because the formation of the anti-oxidation film 50 is achieved by simply depositing the anti-oxidation metal film 80 over the exposed surfaces of the chamber plate 10 and vibrating plate 20. In this case, however, the formation efficiency of the anti-oxidation film 50 is degraded as compared to the first embodiment.

In accordance with the second embodiment, it is possible to prevent the vibrating plate 20 from varying in physical properties or shape during the processing step for sintering the oxide piezoelectric element 60 deposited over the vibrating plate 20 at a high temperature.

Fig. 3 illustrates a method for fabricating an actuator of an inkjet printer head in accordance with a third embodiment of the present invention. In Fig. 3, elements respectively corresponding to those of Figs. 1 and 2 are denoted by the same reference numerals. Referring to the uppermost view of Fig. 3, a

vibrating plate 20 is shown which is formed integrally with a chamber plate 10 provided with a solution chamber 11.

The chamber plate 10 and vibrating plate 20 are made of a material containing an anti-oxidation metal.

When the chamber plate 10 and vibrating plate 20, which contain an anti-oxidation metal, are subjected to a thermal treatment at a temperature of about 600 to 1,500°C, the exposed surfaces thereof are oxidized, thereby forming an anti-oxidation film 50 thereon.

Preferably, the anti-oxidation film 50 has a thickness of about 0.03 to 5 μm, as in the previous embodiments of the present invention.

Thereafter, an oxide piezoelectric element 60 is deposited on a desired portion of the vibrating plate 20 formed with the anti-oxidation film 50, and then sintered at a high temperature of about 900 to 1,100°C. Finally, an upper electrode 70 is laminated over the oxide piezoelectric element 60. Thus, an inkjet printer head is produced.

Fig. 4 illustrates a method for fabricating an actuator of an inkjet printer head in accordance with a fourth embodiment of the present invention. In Fig. 4, elements respectively corresponding to those of Fig. 1 are denoted by the same reference numerals. This embodiment is characterized in that a vibrating plate 20 is formed integrally with a chamber plate 10 provided with no solution chamber. In accordance with this embodiment, the chamber plate 10 is formed with a desired solution chamber at a final processing step.

Where the chamber plate 10 provided with the solution chamber 11 is used as in the first to the third embodiments, the vibrating plate 20 covering the upper portion of the solution chamber 11 may vary in physical properties during a thermal treatment conducted at a high temperature in the formation of the anti-oxidation film 50 because it is comprised of a thin plate.

When the vibrating plate 20 is thermally treated at a high temperature of about 600 to 1,500°C to form an anti-oxidation film, it may vary in physical properties, so that it may be deformed.

For this reason, in accordance with the fourth embodiment of the present invention, the vibrating plate 20 is coupled to the chamber plate 10 formed with no solution chamber so that it is prevented from varying in physical properties during a thermal treatment at a high temperature.

In accordance with the fourth embodiment, the structure including the chamber plate 10 and vibrating plate 20 integral with each other is then loaded in a container received in a heating furnace 30, together with metal powder 40 to be coated over the exposed surfaces of the chamber plate 10 and vibrating plate 20.

For the metal powder 40, aluminum or chromium may be mainly used which exhibit an anti-oxidation property. Nickel or cobalt may be added to the aluminum or chromium.

An active agent adapted to provide an active coating of the metal powder 40 and an anti-sintering agent adapted to prevent the metal powder 40 from flowing and being sintered may be added

in the furnace 30 in the form of powder in certain ratios with respect to the metal powder 40, respectively.

The active agent may include a halogen compound such as sodium chloride (NaCl) or nitrogen chloride ($NH_4Cl$). The anti-sintering agent may include alumina oxide ($Al_2O_3$) or zirconia ($ZrO_2$).

The furnace 30 is then heated at a high temperature in a desired atmosphere, for example, a reducing atmosphere containing reducing gas such as hydrogen ($H_2$) or an inert atmosphere containing inert gas such as argon (Ar), helium (He), or nitrogen ($N_2$), and/or in a vacuum condition of $10^{-5}$ to 50 Torr. As the furnace 30 is heated, the metal powder 40 is melted, so that it is coated over the exposed surfaces of the chamber plate 10 and vibrating plate 20, thereby forming an anti-oxidation metal film 80 over the exposed surfaces of the chamber plate 10 and vibrating plate 20.

Preferably, the heating temperature of the furnace 30 is about 500°C or more.

The resulting structure coated with the anti-oxidation metal film 80 is thermally treated at a temperature of about 600 to 1,500°C in an oxidation atmosphere. By this thermal treatment, the metal film 80 coated over the exposed surfaces of the chamber plate 10 and vibrating plate 20 is oxidized, thereby forming an anti-oxidation film 50 over the exposed surfaces of those plates 10 and 20.

The anti-oxidation film 50 is very tight, namely, has a very high inter-grain density, so that it is prevented from being

oxidized in the surface thereof.

Preferably, the anti-oxidation film 50 has a thickness of about 0.03 to 5 μm. Where the anti-oxidation film 50 has an excessive thickness, the vibrating performance of the vibrating plate 20 is greatly degraded.

Thereafter, an oxide piezoelectric element 60 is deposited on a desired portion of the vibrating plate 20 formed with the anti-oxidation film 50 using a screen printing process, and then sintered at a high temperature of about 900 to 1,100°C. An upper electrode 70 is then laminated over the oxide piezoelectric element 60.

Finally, a solution chamber 11 is formed at the lower surface of the chamber plate 10.

In order to form the solution chamber 11, a photoresist film 90 is first coated over the lower surface of the chamber plate 10 and then appropriately patterned using a mask in accordance with light exposure, development and rinsing processes. That is, the photoresist film 90 is partially removed to leave a pattern having an area less than or equal to that of the solution chamber 11 to be formed. Using the photoresist pattern as a mask, the chamber plate 10 is then etched, thereby forming the solution chamber 11.

Thus, a desired inkjet printer head is produced.

Fig. 6 illustrates a method for fabricating an actuator of an inkjet printer head in accordance with a fifth embodiment of the present invention. In Fig. 6, elements respectively corresponding to those of Figs. 4 and 5 are denoted by the same

reference numerals. This embodiment is similar to the fourth embodiment in that a vibrating plate 20 is formed integrally with a chamber plate 10 provided with no solution chamber, as in the fourth embodiment.

In accordance with this embodiment, an anti-oxidation metal film 80 is deposited over the exposed surfaces of the chamber plate 10 and vibrating plate 20 by use of a vacuum deposition process such as a sputtering or evaporation process.

The deposition of the anti-oxidation metal film 80 may be achieved by depositing an oxidized metallic material over the exposed surfaces of the chamber plate 10 and vibrating plate 20. Alternatively, the deposition of the anti-oxidation metal film 80 may be achieved by depositing a metallic material containing an anti-oxidation metal.

Although the anti-oxidation metal film 80 is already in an oxidized state, its oxidation is further carried out when the chamber plate 10 and vibrating plate 20 deposited with the anti-oxidation metal film 80 are subjected to a thermal treatment at a temperature of about 600 to 1,500°C. As a result, a tight anti-oxidation film 50 with a very high density is formed over the exposed surfaces of the chamber plate 10 and vibrating plate 20.

Preferably, the anti-oxidation film 50 has a thickness of about 0.03 to 5 μm, as in the first embodiment of the present invention.

Thereafter, an oxide piezoelectric element 60 is deposited on a desired portion of the vibrating plate 20 formed with the

anti-oxidation film 50, and then sintered at a high temperature of about 900 to 1,100°C. An upper electrode 70 is then deposited over the oxide piezoelectric element 60.

Finally, a solution chamber 11 is formed at the lower surface of the chamber plate 10.

In order to form the solution chamber 11, a photoresist film 90 is first coated over the lower surface of the chamber plate 10 and then appropriately patterned using a mask in accordance with light exposure, development and rinsing processes. That is, the photoresist film 90 is partially removed to leave a pattern having an area less than or equal to that of the solution chamber 11 to be formed. Using the photoresist pattern as a mask, the chamber plate 10 is then etched, thereby forming the solution chamber 11.

Thus, a desired inkjet printer head is produced.

Fig. 7 illustrates a method for fabricating an actuator of an inkjet printer head in accordance with a sixth embodiment of the present invention. In Fig. 7, elements respectively corresponding to those of Figs. 4 to 6 are denoted by the same reference numerals. This embodiment is similar to the third embodiment, except that a vibrating plate 20 is formed integrally with a chamber plate 10 provided with no solution chamber. In accordance with the sixth embodiment of the present invention, the chamber plate 10 and vibrating plate 20 are made of a material containing an anti-oxidation metal, as in the third embodiment.

When the chamber plate 10 and vibrating plate 20, which

contain an anti-oxidation metal, are subjected to a thermal treatment at a temperature of about 600 to 1,500°C, the exposed surfaces thereof are oxidized, thereby forming a tight anti-oxidation film 50 with a very high density thereon.

Preferably, the anti-oxidation film 50 has a thickness of about 0.03 to 5 μm.

Thereafter, an oxide piezoelectric element 60 is deposited on a desired portion of the vibrating plate 20 formed with the anti-oxidation film 50, and then sintered at a high temperature of about 900 to 1,100°C. An upper electrode 70 is then deposited over the oxide piezoelectric element 60.

Finally, a solution chamber 11 is formed at the lower surface of the chamber plate 10, as in the fourth and fifth embodiments.

In order to form the solution chamber 11, a photoresist film 90 is first coated over the lower surface of the chamber plate 10 and then appropriately patterned using a mask in accordance with light exposure, development and rinsing processes. That is, the photoresist film 90 is partially removed to leave a pattern having an area less than or equal to that of the solution chamber 11 to be formed. Using the photoresist pattern as a mask, the chamber plate 10 is then etched, thereby forming the solution chamber 11.

Thus, a desired inkjet printer head is produced.

Fig. 8 illustrates a method for fabricating an actuator of an inkjet printer head in accordance with a seventh embodiment of the present invention. In Fig. 8, elements respectively

corresponding to those of Fig. 1 are denoted by the same reference numerals. In accordance with this embodiment, a vibrating plate 20 is formed integrally with a chamber plate 10 provided with a solution chamber 11, as in the first embodiment. The resultant structure including the chamber plate 10 and vibrating plate 20 integral with each other is then loaded in a container received in a heating furnace 30, together with metal powder 40 to be coated over exposed surfaces of the chamber plate 10 and vibrating plate 20.

For the metal powder 40, aluminum or chromium may be mainly used which exhibit an anti-oxidation property. Nickel or cobalt may be added to the aluminum or chromium.

An active agent adapted to provide an active coating of the metal powder 40 and an anti-sintering agent adapted to prevent the metal powder 40 from flowing and being sintered may be added in the furnace 30 in the form of powder in certain ratios with respect to the metal powder 40, respectively.

The active agent may include a halogen compound such as sodium chloride ($NaCl$) or nitrogen chloride ($NH_4Cl$). The anti-sintering agent may include alumina oxide ($Al_2O_3$) or zirconia ($ZrO_2$).

The furnace 30 is then heated at a high temperature in a desired atmosphere, for example, a reducing atmosphere containing reducing gas such as hydrogen ($H_2$) or an inert atmosphere containing inert gas such as argon (Ar), helium (He), or nitrogen ($N_2$), and/or in a vacuum condition of $10^{-5}$ to 50 Torr.

Preferably, the heating temperature of the furnace 30 is

about 500°C or more.

As the furnace 30 is heated, the metal powder 40 is melted, so that it is coated over the exposed surfaces of the chamber plate 10 and vibrating plate 20 contained in the container, thereby forming an anti-oxidation metal film 80 over the exposed surfaces of the chamber plate 10 and vibrating plate 20.

Thereafter, an oxide piezoelectric element 60 is deposited on a desired portion of the vibrating plate 20 formed with the anti-oxidation metal film 80, and then sintered in accordance with a thermal treatment in an oxidation atmosphere. By this thermal treatment, the metal film 80 coated over the exposed surfaces of the chamber plate 10 and vibrating plate 20 is also oxidized, thereby forming an anti-oxidation film 50 over the exposed surfaces of those plates 10 and 20.

As compared to the first embodiment, this seventh embodiment is characterized in that the formation of the anti-oxidation film 50 is achieved upon sintering the oxide piezoelectric element 60 laminated on the vibrating plate 20. In the case of the first embodiment, the formation of the anti-oxidation film 50 is achieved prior to the lamination of the oxide piezoelectric element 60.

Finally, an upper electrode 70 is laminated over the sintered oxide piezoelectric element 60. Thus, an inkjet printer head is produced.

Fig. 9 illustrates a method for fabricating an actuator of an inkjet printer head in accordance with an eighth embodiment of the present invention. In Fig. 9, elements respectively

corresponding to those of Fig. 8 are denoted by the same reference numerals. This embodiment is different from the seventh embodiment and similar to the fourth embodiment in that a vibrating plate 20 is formed integrally with a chamber plate 10 provided with no solution chamber. In accordance with this embodiment, the chamber plate 10 is formed with a desired solution chamber at a final processing step.

In accordance with the eighth embodiment, the structure including the chamber plate 10 and vibrating plate 20 integral with each other is then loaded in a container received in a heating furnace 30, together with metal powder 40 to be coated over the exposed surfaces of the chamber plate 10 and vibrating plate 20.

For the metal powder 40, aluminum or chromium may be mainly used which exhibit an anti-oxidation property. Nickel or cobalt may be added to the aluminum or chromium.

An active agent adapted to provide an active coating of the metal powder 40 and an anti-sintering agent adapted to prevent the metal powder 40 from flowing and being sintered may be added in the furnace 30 in the form of powder in certain ratios with respect to the metal powder 40, respectively.

The active agent may include a halogen compound such as sodium chloride ($NaCl$) or nitrogen chloride ($NH_4Cl$). The anti-sintering agent may include alumina oxide ($Al_2O_3$) or zirconia ($ZrO_2$).

The furnace 30 is then heated at a high temperature in a desired atmosphere, for example, a reducing atmosphere containing reducing gas such as hydrogen ($H_2$) or an inert atmosphere

containing inert gas such as argon (Ar), helium (He), or nitrogen ($N_2$), and/or in a vacuum condition of $10^{-5}$ to 50 Torr.

Preferably, the heating temperature of the furnace 30 is about 500°C or more.

As the furnace 30 is heated, the metal powder 40 is melted, so that it is coated over the exposed surfaces of the chamber plate 10 and vibrating plate 20, thereby forming an anti-oxidation metal film 80 over the exposed surfaces of the chamber plate 10 and vibrating plate 20.

Thereafter, an oxide piezoelectric element 60 is deposited on a desired portion of the vibrating plate 20 formed with the anti-oxidation metal film 80, and then sintered in accordance with a thermal treatment in an oxidation atmosphere. By this thermal treatment, the metal film 80 coated over the exposed surfaces of the chamber plate 10 and vibrating plate 20 is also oxidized, thereby forming an anti-oxidation film 50 over the exposed surfaces of those plates 10 and 20.

The sintering temperature is about 600 to 1,500°C.

An upper electrode 70 is then laminated over the oxide piezoelectric element 60. Subsequently, a photoresist film 90 is coated over the lower surface of the chamber plate 10 and then appropriately patterned using a mask in accordance with light exposure, development and rinsing processes. That is, the photoresist film 90 is partially removed to leave a pattern having an area less than or equal to that of a solution chamber to be formed. Using the photoresist pattern as a mask, the chamber plate 10 is then etched, thereby forming a solution

chamber 11.

Thus, a desired inkjet printer head is produced.

In the above mentioned embodiment, the anti-oxidation film 50 coated over the exposed surfaces of the chamber plate 10 and vibrating plate 20 is comprised of a chromium oxide film or aluminum oxide film. In order to form such an anti-oxidation film 50, it is desirable to carry out the thermal treatment in an oxidation atmosphere for about one hour or more.

The anti-oxidation film 50, which is comprised of a chromium oxide film or aluminum oxide film, is very stable because it is a tight oxide film with a high density. Since no further oxidation is carried out after a certain oxidation time elapses, the anti-oxidation film 50 is formed to a constant thickness.

For instance, where the chamber plate 10 and vibrating plate 20 are mainly made of nickel, and chromium, which is an anti-oxidation metal, is deposited over those plates 10 and 20 in the furnace 30 as in the first, the fourth, and the eighth embodiments of the present invention, the resultant structure exhibits a composition ratio between nickel and chromium shown in Fig. 10A in the chromium-deposited state. Referring to FIG. 10A, it can be found that a chromium layer, which is an anti-oxidation metal, is formed to a certain thickness over the surface of a substrate, namely, a nickel substrate. When this structure is thermally treated at a temperature of about 600 to 1,500°C, the composition ratio between nickel and chromium varies sharply at the boundary between the nickel substrate and chromium layer, as shown in Fig. 10B. When the thermal treatment is carried out in

an oxidation atmosphere, the portion of the chromium layer existing at the boundary between the nickel substrate and chromium layer is changed into a chromium oxide film which is an anti-oxidation film. At this time, the portion of the nickel substrate existing at the boundary between the nickel substrate and chromium layer is changed into a chromium-nickel alloy film containing chromium in a reduced content and nickel in an increased content at an increased depth of the nickel substrate.

That is, the chromium layer is gradually changed into a chromium oxide film from the surfaces of the chamber plate 10 and vibrating plate 20 in accordance with its oxidation. Thus, a tight anti-oxidation film with a high density is formed on and in the surfaces of the chamber plate 10 and vibrating plate 20. The anti-oxidation film exhibits a reduced density at an increased depth of the chamber plate 10 and vibrating plate 20. The nickel substrate is still maintained at a certain depth of the chamber plate 10 and vibrating plate 20.

The anti-oxidation film formed over the chamber plate 10 and vibrating plate 20 after the oxidation serves to prevent oxygen from penetrating into the chamber plate 10 and vibrating plate 20, thereby preventing those plates 10 and 20 from being further oxidized. The anti-oxidation film also exhibits a resistance to heat of a high temperature. Accordingly, the chamber plate 10 and vibrating plate 20 can be maintained in a stable state.

In particular, where the formation of the anti-oxidation film 50 over the vibrating plate 20 is achieved prior to or simultaneously with the sintering of the oxide piezoelectric element 60, the vibrating plate 20 is not influenced by heat of

a high temperature used in the sintering of the oxide piezoelectric element 60. Accordingly, it is possible to prevent the vibrating plate 20 from varying in physical properties or shape.

Where the anti-oxidation film 50 is also formed over the inner surface of the solution chamber 11 defined in the chamber plate 10, it is possible to prevent the portions of the chamber plate 10 and vibrating plate 20 defining the solution chamber 11 from being eroded by ink contacting them.

Since the anti-oxidation film 50 generally exhibits an insulation property, the formation of a lower electrode may be achieved using a thick film formation process such as a screen printing process, prior to the deposition of the oxide piezoelectric element 60 on the vibrating plate 20. Electric lines may also be formed on the anti-oxidation film 50 so as to achieve a stable supply of voltage to the oxide piezoelectric element 60.

Where the anti-oxidation metal film 80 laminated over the chamber plate 10 and vibrating plate 20 is thermally treated in an oxidation atmosphere, it is oxidized and changed into the anti-oxidation film 50. During such an oxidation, a considerable variation in volume occurs in the chamber plate 10 and vibrating plate 20.

For this reason, the coupling between the chamber plate 10 and vibrating plate 20 may be insufficiently achieved where the anti-oxidation film 50 is formed only over the vibrating plate 20. Accordingly, it is most preferred that the formation of the anti-oxidation film 50 be carried out after the chamber plate 10

and vibrating plate 20 are integrally coupled together.

Where the printer head fabrication is carried out in the above mentioned manner, there is no problem even though the vibrating plate 20 is slightly deformed. This is because the deformation of the vibrating plate 20 occurs simultaneously with a deformation of the chamber plate 10. Consequently, there is a beneficial advantage in that the printer head fabricated as mentioned above can be surely protected from external influences.

Although the preferred embodiments of the invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.

CLAIMS

1. A method for fabricating an actuator of an inkjet printer head comprising the steps of:

forming a vibrating plate in such a fashion that it is integrally with a chamber plate having a solution chamber;

mixing metal powder, to be coated over said chamber plate and said vibrating plate integrally coupled together, with an active agent adapted to activate said coating process and an anti-sintering agent adapted to prevent said metal powder from flowing and being sintered, in a desired composition ratio, thereby producing a powder mixture, and then loading the mixture along with said chamber plate and said vibrating plate into a furnace;

heating said furnace at a high temperature in a desired atmosphere, thereby forming an anti-oxidation metal film over exposed surfaces of said chamber plate and said vibrating plate;

thermally treating said chamber plate and said vibrating plate in an oxidation atmosphere in such a fashion that said anti-oxidation metal film is oxidized, thereby forming an anti-oxidation film over said exposed surfaces of said chamber plate and said vibrating plate;

depositing an oxide piezoelectric element on an upper surface of said vibrating plate coated with said anti-oxidation film in accordance with a sintering process; and

laminating an upper electrode over said oxide piezoelectric element.

2. The method in accordance with Claim 1, wherein said metal powder mainly contains aluminum.

3. The method in accordance with Claim 1, wherein said metal powder mainly contains chromium.

4. The method in accordance with Claim 1, wherein said metal powder contains aluminum and chromium added with nickel and cobalt.

5. The method in accordance with Claim 1, wherein said atmosphere of said furnace is a reducing atmosphere.

6. The method in accordance with Claim 1, wherein said atmosphere of said furnace is an inert atmosphere containing inert gas.

7. The method in accordance with Claim 1, wherein said atmosphere of said furnace is a vacuum atmosphere of about $10^{-5}$ to 50 Torr.

8. The method in accordance with Claim 1, wherein said thermal treatment for said chamber plate and said vibrating plate in said oxidation atmosphere is carried out at a temperature of about 600 to 1,500°C.

9. A method for fabricating an actuator of an inkjet printer head comprising the steps of:

forming a vibrating plate in such a fashion that it is integrally with a chamber plate having a solution chamber;

depositing an anti-oxidation metal film over exposed surfaces of said chamber plate and said vibrating plate integrally coupled together in accordance with a vacuum deposition process;

thermally treating said chamber plate and said vibrating plate in such a fashion that said anti-oxidation metal film is

oxidized, thereby forming an anti-oxidation film over said exposed surfaces of said chamber plate and said vibrating plate;

depositing an oxide piezoelectric element on an upper surface of said vibrating plate coated with said anti-oxidation film in accordance with a sintering process; and

laminating an upper electrode over said oxide piezoelectric element.

10. The method in accordance with Claim 9, wherein said metal powder mainly contains aluminum.

11. The method in accordance with Claim 9, wherein said metal powder mainly contains chromium.

12. The method in accordance with Claim 9, wherein said metal powder contains aluminum and chromium added with nickel and cobalt.

13. The method in accordance with Claim 9, wherein said anti-oxidation metal film is in an oxidized state prior to the lamination thereof.

14. The method in accordance with Claim 9, wherein said anti-oxidation metal film contains an anti-oxidation metal.

15. The method in accordance with Claim 9, wherein said thermal treatment for said chamber plate and said vibrating plate is carried out at a temperature of about 600 to 1,500°C.

16. A method for fabricating an actuator of an inkjet printer head comprising the steps of:

forming a vibrating plate containing an anti-oxidation metal in such a fashion that it is integrally with a chamber plate having a solution chamber;

thermally treating, at a high temperature, said chamber plate and said vibrating plate integrally coupled together in such a fashion that they are oxidized at their exposed surfaces, thereby forming an anti-oxidation film over said exposed surfaces;

depositing an oxide piezoelectric element on an upper surface of said vibrating plate coated with said anti-oxidation film in accordance with a sintering process; and

laminating an upper electrode over said oxide piezoelectric element.

17. The method in accordance with Claim 16, wherein said metal powder mainly contains aluminum.

18. The method in accordance with Claim 16, wherein said metal powder mainly contains chromium.

19. The method in accordance with Claim 16, wherein said thermal treatment for said chamber plate and said vibrating plate is carried out at a temperature of about 600 to 1,500°C.

20. A method for fabricating an actuator of an inkjet printer head comprising the steps of:

forming a vibrating plate in such a fashion that it is integrally with a chamber plate having no solution chamber;

mixing metal powder, to be coated over said chamber plate and said vibrating plate integrally coupled together, with an active agent adapted to activate said coating process and an anti-sintering agent adapted to prevent said metal powder from flowing and being sintered, in a desired composition ratio, thereby producing a powder mixture, and then loading the mixture

along with said chamber plate and said vibrating plate into a furnace;

heating said furnace at a high temperature in a desired atmosphere, thereby forming an anti-oxidation metal film over exposed surfaces of said chamber plate and said vibrating plate;

thermally treating said chamber plate and said vibrating plate in an oxidation atmosphere in such a fashion that said anti-oxidation metal film is oxidized, thereby forming an anti-oxidation film over said exposed surfaces of said chamber plate and said vibrating plate;

depositing an oxide piezoelectric element on an upper surface of said vibrating plate coated with said anti-oxidation film in accordance with a sintering process;

laminating an upper electrode over said oxide piezoelectric element; and

patterning said chamber plate, thereby defining a solution chamber in said chamber plate.

21. The method in accordance with Claim 20, wherein said metal powder mainly contains aluminum.

22. The method in accordance with Claim 20, wherein said metal powder mainly contains chromium.

23. The method in accordance with Claim 20, wherein said metal powder contains aluminum and chromium added with nickel and cobalt.

24. The method in accordance with Claim 20, wherein said atmosphere of said furnace is a reducing atmosphere.

25. The method in accordance with Claim 20, wherein said atmosphere of said furnace is an inert atmosphere containing

inert gas.

26. The method in accordance with Claim 20, wherein said atmosphere of said furnace is a vacuum atmosphere of about $10^{-5}$ to 50 Torr.

27. The method in accordance with Claim 20, wherein said thermal treatment for said chamber plate and said vibrating plate in said oxidation atmosphere is carried out at a temperature of about 600 to 1,500°C.

28. A method for fabricating an actuator of an inkjet printer head comprising the steps of:

forming a vibrating plate in such a fashion that it is integrally with a chamber plate having no solution chamber;

depositing an anti-oxidation metal film over exposed surfaces of said chamber plate and said vibrating plate integrally coupled together in accordance with a vacuum deposition process;

thermally treating said chamber plate and said vibrating plate in such a fashion that said anti-oxidation metal film is oxidized, thereby forming an anti-oxidation film over said exposed surfaces of said chamber plate and said vibrating plate;

depositing an oxide piezoelectric element on an upper surface of said vibrating plate coated with said anti-oxidation film in accordance with a sintering process;

laminating an upper electrode over said oxide piezoelectric element; and

patterning said chamber plate, thereby defining a solution chamber in said chamber plate.

29. The method in accordance with Claim 28, wherein said metal powder mainly contains aluminum.

30. The method in accordance with Claim 28, wherein said metal powder mainly contains chromium.

31. The method in accordance with Claim 28, wherein said metal powder contains aluminum and chromium added with nickel and cobalt.

32. The method in accordance with Claim 28, wherein said anti-oxidation metal film is in an oxidized state prior to the lamination thereof.

33. The method in accordance with Claim 28, wherein said anti-oxidation metal film contains an anti-oxidation metal.

34. The method in accordance with Claim 28, wherein said thermal treatment for said chamber plate and said vibrating plate is carried out at a temperature of about 600 to 1,500°C.

35. A method for fabricating an actuator of an inkjet printer head comprising the steps of:

forming a vibrating plate containing an anti-oxidation metal in such a fashion that it is integrally with a chamber plate having no solution chamber;

thermally treating, at a high temperature, said chamber plate and said vibrating plate integrally coupled together in such a fashion that they are oxidized at their exposed surfaces, thereby forming an anti-oxidation film over said exposed surfaces;

depositing an oxide piezoelectric element on an upper surface of said vibrating plate coated with said anti-oxidation

film in accordance with a sintering process;

laminating an upper electrode over said oxide piezoelectric element; and

patterning said chamber plate, thereby defining a solution chamber in said chamber plate.

36. The method in accordance with Claim 35, wherein said metal powder mainly contains aluminum.

37. The method in accordance with Claim 35, wherein said metal powder mainly contains chromium.

38. The method in accordance with Claim 35, wherein said thermal treatment for said chamber plate and said vibrating plate is carried out at a temperature of about 600 to 1,500°C.

39. A method for fabricating an actuator of an inkjet printer head comprising the steps of:

forming a vibrating plate in such a fashion that it is integrally with a chamber plate having a solution chamber;

mixing metal powder, to be coated over said chamber plate and said vibrating plate integrally coupled together, with an active agent adapted to activate said coating process and an anti-sintering agent adapted to prevent said metal powder from flowing and being sintered, in a desired composition ratio, thereby producing a powder mixture, and then loading the mixture along with said chamber plate and said vibrating plate into a furnace;

heating said furnace at a high temperature in a desired atmosphere, thereby forming an anti-oxidation metal film over exposed surfaces of said chamber plate and said vibrating plate;

depositing an oxide piezoelectric element on an upper surface of said vibrating plate coated with said anti-oxidation metal film, and sintering said oxide piezoelectric element in an oxidation atmosphere in accordance with a sintering process while oxidizing exposed surfaces of said chamber plate and said vibrating plate; and

laminating an upper electrode over said oxide piezoelectric element.

40. The method in accordance with Claim 39, wherein said metal powder mainly contains aluminum.

41. The method in accordance with Claim 39, wherein said metal powder mainly contains chromium.

42. The method in accordance with Claim 39, wherein said metal powder contains aluminum and chromium added with nickel and cobalt.

43. The method in accordance with Claim 39, wherein said atmosphere of said furnace is a reducing atmosphere.

44. The method in accordance with Claim 39, wherein said atmosphere of said furnace is an inert atmosphere containing inert gas.

45. The method in accordance with Claim 39, wherein said atmosphere of said furnace is a vacuum atmosphere of about $10^{-5}$ to 50 Torr.

46. The method in accordance with Claim 39, wherein said thermal treatment for said chamber plate and said vibrating plate in said oxidation atmosphere is carried out at a temperature of about 600 to 1,500°C.

47. A method for fabricating an actuator of an inkjet printer head comprising the steps of:

forming a vibrating plate in such a fashion that it is integrally with a chamber plate having no solution chamber;

mixing metal powder, to be coated over said chamber plate and said vibrating plate integrally coupled together, with an active agent adapted to activate said coating process and an anti-sintering agent adapted to prevent said metal powder from flowing and being sintered, in a desired composition ratio, thereby producing a powder mixture, and then loading the mixture along with said chamber plate and said vibrating plate into a furnace;

heating said furnace at a high temperature in a desired atmosphere, thereby forming an anti-oxidation metal film over exposed surfaces of said chamber plate and said vibrating plate;

depositing an oxide piezoelectric element on an upper surface of said vibrating plate coated with said anti-oxidation metal film, and sintering said oxide piezoelectric element in an oxidation atmosphere in accordance with a sintering process while oxidizing exposed surfaces of said chamber plate and said vibrating plate;

laminating an upper electrode over said oxide piezoelectric element; and

patterning said chamber plate, thereby defining a solution chamber in said chamber plate.

48. The method in accordance with Claim 47, wherein said metal powder mainly contains aluminum.

49. The method in accordance with Claim 47, wherein said metal

powder mainly contains chromium.

50. The method in accordance with Claim 47, wherein said metal powder contains aluminum and chromium added with nickel and cobalt.

51. The method in accordance with Claim 47, wherein said atmosphere of said furnace is a reducing atmosphere.

52. The method in accordance with Claim 47, wherein said atmosphere of said furnace is an inert atmosphere containing inert gas.

53. The method in accordance with Claim 47, wherein said atmosphere of said furnace is a vacuum atmosphere of about $10^{-5}$ to 50 Torr.

54. The method in accordance with Claim 47, wherein said thermal treatment for said chamber plate and said vibrating plate in said oxidation atmosphere is carried out at a temperature of about 600 to 1,500°C.